Quantitative Evaluations of the Effects of the Seabed Sediments on the Scattering and Propagation of Low to Medium Frequency Acoustic Energy in the Shallow Oceans

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LONG -TERM GOALS

To quantitatively understand the physics of propagation, scattering, and attenuation of low to medium frequency (100-15000 Hz) acoustic waves in shallow waters and seabed sediments.

OBJECTIVES

The first objective is to quantitatively understand the effects of seabed scattering mechanisms (volume fluctuation, bottom and sub-bottom roughness) on the acoustic propagation, scattering and attenuation. This includes the effects of poro-elastic properties of the sediments on the propagation of acoustic waves. The second objective is the quantitative understanding of the spatial and temporal fluctuations (amplitude and phase coherency) of acoustic wave fields in shallow water.

APPROACH

During SWAT2000 experiments, we (PI, H. Yamaoka, and H. Sun) successfully collected wave propagation data among three 5 m high rigid towers to which a broadband source (center frequency 5.5 kHz) and a hydrophone each are attached. The sides of the propagation triangle are 3, 4, and 5 km in range. The triangle array was deployed at SS site (water depth 80 m, sand bottom) and OS (water depth 120 m, clay bottom) site. The duration of pulse propagation were 36 hours at SS site and 16 hours at OS site. The pulse transmission intervals are 2 minuets and 20 minuets. Sufficient environmental data were measured by CTD, cores by Dr. D. Lavoie, and high-resolution reflection data by Dr. A. Turgut were taken at the two sites. This will give a very interesting model – data comparisons for learning the effects of bottom and water column fluctuations on acoustic wave propagation in shallow waters. The acoustic wave field arrival data are totally different between the two sites. Modeling of wave propagation is now being performed using a PE code by PI and H. Yamaoka. A NRL group headed by Dr. Bob Field is also making a model – data comparison at OS site using our propagation data.

Monostatic scattering and bistatic scattering from seabeds have been investigated using the bilinear hydrophone array deployed at a sand bottom and a clay bottom by PI and Hua Sun. The results will be published soon.

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14. ABSTRACT
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15. SUBJECT TERMS

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Imaging the permeability structure in the sediments and rocks is an important unsolved problem of geoacoustics and geophysics. I have successfully solved this problem analytically for two cases for which the Biot theory becomes second order equations. One is near surface sediments and another is high permeability limestone. I will like to solve this problem for general cases. I am working with Junichi Sakakibara of Kawasaki Steel Corporation who provided cross-well tomography data from which I extract permeability.

WORK COMPLETED

1. The SWAT2000 propagation experiments at 5.5 kHz using three fixed source-receiver towers at SS site and OS site have been successfully completed (Figs. 1 and 2). The PE code is used to model the complicated acoustics propagation.

2. The bistatic and momostatic scattering data at 3.75, 7.5 and 15 kHz acquired during the 1999 cruise in Gulf of Mexico near Gulf Port, Mississippi have been analyzed (Sun and Yamamoto, 2001).

3. The permeability image inversion algorism for near surface sediments has been developed based on the Biot theory. The permeability image in Tokyo Bay sediments was successfully extracted from cross-hole tomography data using this code (Yamamoto, 2001a).

4. The permeability image inversion algorism for carbonate rocks has been coded based on the Super-K theory. The permeability images in South Florida's deep and shallow aquifers were successfully extracted using this code from cross-well tomography data (Yamamoto, 2001b).

RESULTS

1. The SWAT2000 propagation experiments at 5.5 kHz using three fixed source-receiver towers at SS site and OS site has been successfully completed (Figs. 1 and 2). The received waveforms at the two sites are very much different. The MMPE code is used to learn what causes such difference. We are learning that the differences in the sound speed structures; bottom structure and free surface roughness at the two sites are all contributing to the difference between the received waveforms at the two sites.

2. The bistatic and momostatic scattering data at 3.75, 7.5 and 15 kHz acquired during the 1999 cruise in Gulf of Mexico near Gulf Port, Mississippi have been analyzed (Sun and Yamamoto, 2001). We learned that the incident waves penetrate the soft clay at all incident angles. The scattering from the soft clay is nearly totally from sediment volume fluctuation.

3. We learned according to the velocity and attenuation measurements that apparent attenuation of acoustic waves within the near surface sediments at medium to high frequency is due to the Biot mechanism and the scattering from the velocity and density fluctuations within sediment volume. The permeability image in Tokyo Bay sediments was successfully extracted from cross-hole tomography data using Biot theory. (Yamamoto, 2001a).

4. The Biot mechanism is enhanced in the high permeability carbonate rocks because the squirt flow mechanism is always relaxed. The permeability image in South Florida limestone aquifers was successfully extracted using this code called Supper-K theory (Yamamoto, 2001b).

IMPACT/APPLICATIONS

The permeability imaging technology developed by the PI has been applied to seabed sediments, deep limestone aquifers, and bedrocks of dams, and been recognized by US EPA in its newsletter (Yamamoto, 2001c).

TRANSITIONS

The Yamamoto volume scattering model of an isotropic- random velocity and density fluctuations is used in 6.2 and 6.3 community for scattering modeling.

The permeability imaging technology developed by the PI has been used to assess the potential of liquefaction of near surface soils by earthquakes and large ocean waves, and the leakage of water from dams (Yamamoto, 2001c; and Mohri et al, 2001).

RELATED PROJECTS

Dr. Altan Turgut of NRL will give us bottom structure data for our acoustic wave propagation modeling. Dr. Dawn Lavoie of NRL-SSC will give us core data at the sites of our acoustic wave propagation. Dr. Bob Field of NRL-SSC will make a model-data comparisons using our propagation data taken at OS site. Mr. Keichi Ohkawa of JDA works as a PhD student under PI’s supervision. At our request, JDA’ Dr. K. Ohota will give us the processed low frequency (800, 1500, and 3000 Hz) data of backscatter and bistatic scatter. We will make data-model comparisons.

I think cross-well tomography is a powerful method to understand the relation between acoustic absorption, scattering loss, and attenuation within the sediments. At the same time underwater cross-hole experiments are difficult and expensive. Tomography measurements from bridges and reclaimed land are easier and less expensive, thus a good substitution to the underwater tests. Professor Masanori Hamada of Waseda University is managing a large project of anti-earthquake technology including liquefaction of ground and subsequent landslides. He has invited me in October 2001 to observe his cross-hole tomography experiment and to extract the permeability image from the velocity and attenuation data.

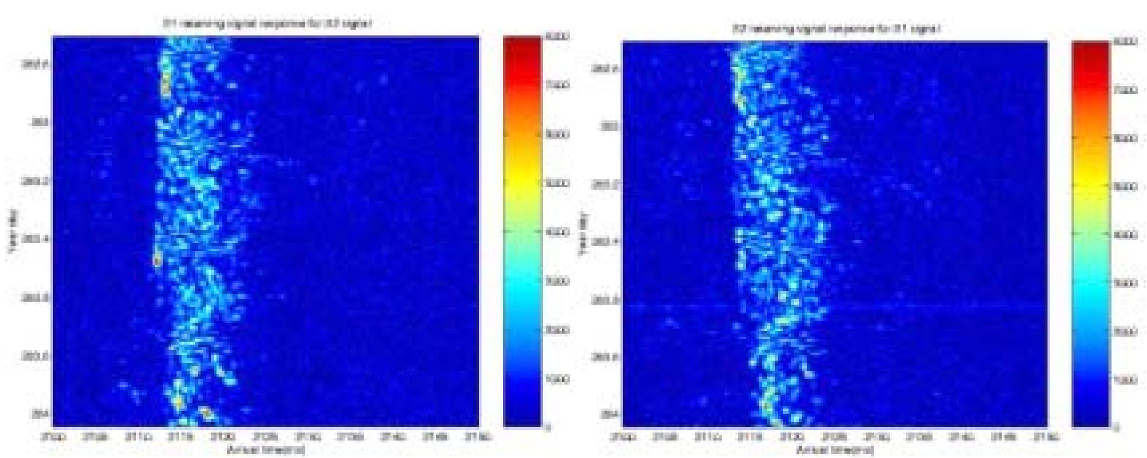

Figure 1 Time plot of receiving signal response. The arrival signals are scattered almost 15ms. The propagation route 1-2 (left) and the reciprocal propagation route 2-1, 3km, at SS site.

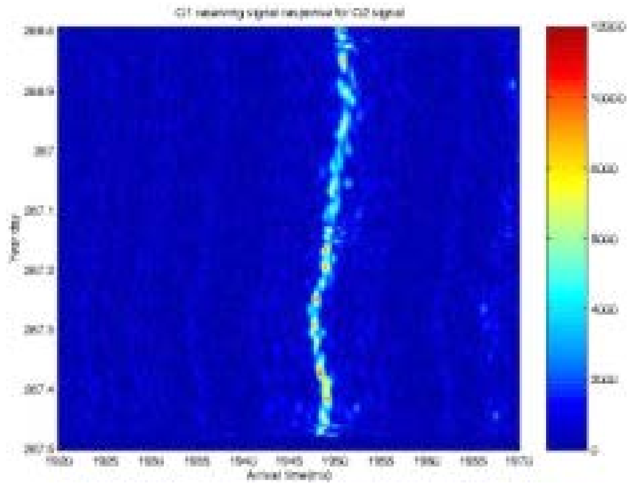

Figure 2 Time plot of receiving signal response of propagation rout 2-1, 3 km at OS site.

REFERENCES

Mohri, E., Sakakibara, J. Yoshimura, K., and Yamamoto, T., ”Method of making a shearing, laminated sediment ground model and its uniformity,” Proceedings of the second symposium for understanding the processes of distraction of structures and improvement of antiearthquake technology, pp 83-88,Tokyo, Japan, March 8-9, (2001).

Sun, H. and Yamamoto, T, “Low grazing angle bistatic bottom scattering on the Gulf of Mexico coastal shelf,” Geoacoustics Laboratory Technical Report No.TR01-1, (2001).

Yamamoto, T. “Imaging the permeability structure within the near-surface sediments by acoustic cross-hole tomography,” Journal of Applied Geophysics, Vol. 47, Issue 1, p. 1-11, (2001a)

Yamamoto,T., ”Imaging Permeability Structure within the Highly Permeable Earth: Theory and Experiment,” Geophysics, Submitted, (2001b)

Yamamoto, T., “Imaging Permeability Structure through Acoustic Cross-well Tomography, “ Ground Water Currents, EPA Newsletter 542-N-01-006, Issue No. 40, July (2001c)

PUBLICATIONS

Mohri,E. ,Sakakibara,J. Yoshimura, K., and Yamamoto, T., ”Method of making a shearing, laminated sediment ground model and its uniformity,” Proceedings of the second symposium for understanding the processes of distraction of structures and improvement of antiearthquake technology, pp 83-88,Tokyo, Japan, March 8-9, (2001). [in Japanese]

Sun, H. and Yamamoto, T, “Low grazing angle bistatic bottom scattering on the Gulf of Mexico coastal shelf,” Geoacoustics Laboratory Technical Report No.TR01, (2001).

Yamamoto, T. “Imaging the permeability structure within the near-surface sediments by acoustic cross-hole tomography,” Journal of Applied Geophysics, Vol. 47, Issue 1, p. 1-11, (2001)

Yamamoto,T., ”Imaging Permeability Structure within the Highly Permeable Earth: Theory and Experiment,” Geophysics, Submitted, (2001)